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Applying Theory of Diffusion of Innovations to Evaluate Technology Acceptance and Sustainability

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Abstract

Integrated Acceptance and Sustainability Assessment Model (IASAM) is a new approach for evaluation of technologies that combines socio-economic aspects and socio-technical characteristics of technology development and exploitation. Previous IASAM model was based on UTAUT acceptance model and it was laborious. The potential acceptance is a very challenging issue and has been studied by many authors. One of the leading theories regarding the acceptance recognition is Theory on Diffusion of Innovations by Rogers. This paper describes the application of this theory in evaluation of technology acceptance and sustainability within the IASAM2 model.

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Keywords: Technology acceptance; Diffusion of Innovations; IASAM; System dynamics simulation.

1. Introduction

There are several theories that reflect the issues of technology acceptance or sustainability, but none of them gives full understanding about the factors influencing acceptance and sustainability combined. Theories such as Technology Acceptance Model (TAM)[1], Unified Theory of Acceptance and Use of Technology (UTAUT)[2], Expectation-Confirmation Theory (ECT) [3] focus mainly on exploitation stage and deal with prediction and modelling of the behaviour of users that make the decision to adopt the technology or reject it. But to invest in elaboration of

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new technologies, one has to be sure that the possibility of failures has been diminished also in the development stage or during testing and maintenance, as different socio-technical factors influencing these stages might also lead to failure of the whole project. Therefore this article explores the system dynamics (SD) simulation based Integrated Acceptance and Sustainability Assessment Model (IASAM). IASAM suggests integrating the acceptance evaluation with other socio-technical factors thus framing united multi-level framework for technology sustainability assessment.

After application of IASAM within the framework of FP7-ICT-2009-5 CHOReOS project No. 257178 (2010-2013) *"Large Scale Choreographies for the Future Internet (IP),* it was concluded to improve the model and to relinquish the potential user survey and search for criteria that could be included in the model. The criteria should give reliable results and ease the use of the model. Thus the IASAM2 version was elaborated.

By introducing IASAM, the authors also propose the concept of technology sustainability for evaluation of the set of socio-technical factors that let the technology to be developed, implemented, maintained properly (according to the needs of all stakeholders) and attract long-term users and create positive output and/or outcome according to the purpose of the technology and initial intentions of its developers (financial, social, etc). [4]

The following sections are organized as follows. Section 2 discusses the need for widening the technology acceptance research focus. The following sections introduce IASAM and theory of diffusion of innovations. The new version of IASAM is compared with initial model and also validated. Finally the conclusion contains a summary of the main ideas of the paper.

2. Widening the technology acceptance research focus

The need for a new approach was supported by a notion that technology acceptance research should not be divided apart from the technological, economical and social evaluation. Only by combining individual factors with both internal (connected with ICTE development management and quality of technology) and external (connected with domain development) socio-technical factors, one is able to have a full understanding of the ICTE development and exploitation.

Different variations of TAM, UTAUT model, ECT are just some to mention in the discussion of technology acceptance and adoption research. They all have their strengths and limitations mainly concerned with the width of focus they have.

Another approach – technology life-cycle approach concentrates on defining universal stages that can be applied to technology and innovation research. In comparison with acceptance research, this approach focuses rather on market forces, management decisions. In the literature, it is common to see the terms industry life cycle, product life cycle and technology life cycle used interchangeably, ambiguously and often inappropriately.[5] But it concentrates rather on commercial/managerial problems and views technology as separate item and does not analyze the differences of the technologies themselves.

But these approaches do not seem to fully answer the question, how to evaluate technology acceptance and sustainability at any chosen point of time of the technology life cycle and forecast the chances of technology to attract users and achieve the aims of its developers, and what are the main elements and factors that influence the acceptance and sustainability of technology?

As an answer to abovementioned problems and lack of answers, the first version of IASAM was created[4] and validated[6]. Validation was carried out by evaluating instant messaging and internet telephony application Skype and then comparing the results with the actual success of Skype.

A brief outline of IASAM structure and development can be found in the next section.

3. IASAM basics and underlying methodology

IASAM consists of four flows that all together constitute what we call technology sustainability. This concept, as mentioned, is used for evaluation of the set of socio-technical factors that impact the way a technology is developed, implemented and maintained, and analyses whether it is done according to the needs of all stakeholders or not, and how it attracts long-term users and creates positive output and/or outcome according to the purpose of the technology and initial intentions of its developers (financial, social, etc). The graphical picture of IASAM can be seen in Fig. 1.

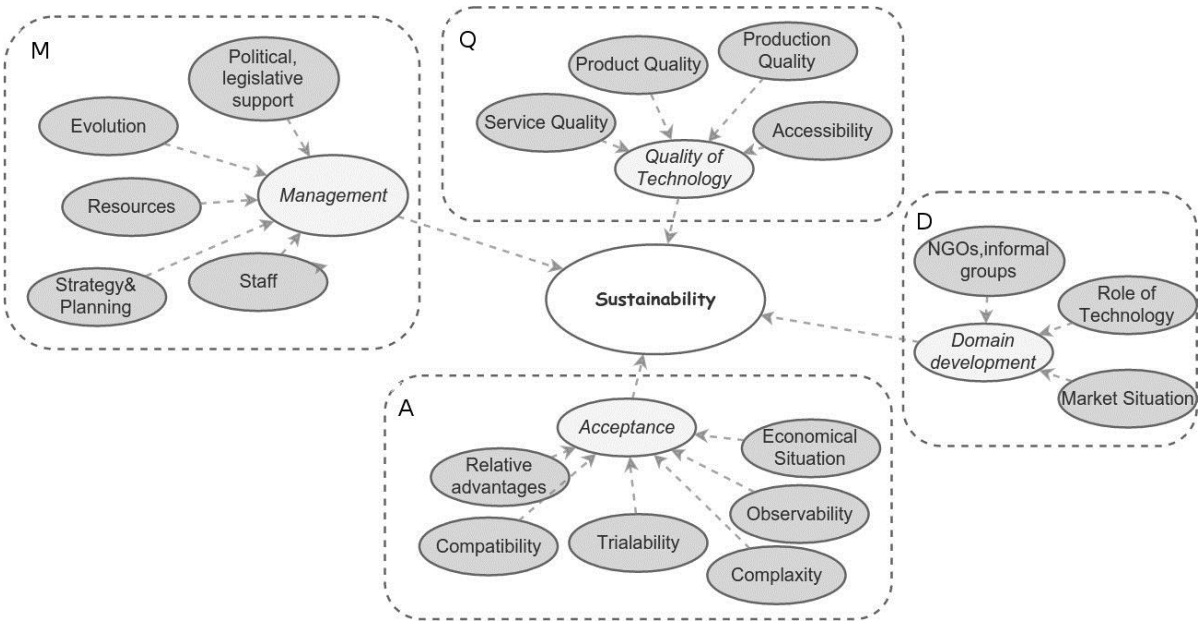

Fig. 1. IASAM model in SD notation (Insight Maker).

As already stated, there are four main flows that shape ICTE sustainability S when $S = \langle M, Q, A, D \rangle$, where M – Management; Q – Quality of technology; A – Acceptance; D – Domain development.

Two internal flows are – Management of ICTE development and exploitation and Quality of technology. And two external flows are – Technology acceptance and Domain development. Each of them includes several socio-technical factors that all together constitute the Integrated Acceptance and Sustainability Assessment Model (IASAM). It is a system dynamics model. System dynamics modelling approach provides the opportunity to simulate a time-varying system with multiple feedback links and analyze quantitative and qualitative factors [7].

The most challenging part of the creation of IASAM was, of course, operationalization of these flows, defining the criteria and measurement instruments. The criteria were defined and after model validation the IASAM was tested under the framework of FP7-ICT-2009-5 CHOReOS project No. 257178 (2010-2013) *"Large Scale Choreographies for the Future Internet (IP)"*[8] to assess CHOReOS project pilots. The experience within this project was also analyzed and it was concluded that the IASAM needs certain amendments to make it more user-friendly and easier without losing its multi-dimensional view. The most important changes were made to user acceptance evaluation part. But first, let`s explain the methodology behind the model.

3.1. Evaluation methodology

IASAM is meant not only for already existing technologies and systems, but also to assess technologies in development process. Therefore it is not possible to use data from technology usage, but only to evaluate planned activities, proposed project or strategy. Because of that, IASAM includes criteria and their descriptions that help to evaluate the criteria and respective set of factors. In short, this approach is based on questionnaire, where each statement has to be evaluated using a certain scale.

The evaluation of criteria is undeniably subjective, but it relies on assumption that every evaluator, whether a technology developer or potential investor, will be concerned to receive possibly reliable evaluation for decision-making. Each IASAM flow consists of several criteria. Each criterion is evaluated with the help of specially formulated criteria description/statement. The respondent evaluates each description.

The model follows these steps:

- The statement provided for each criterion is evaluated in 7 point Likert scale. If it is not possible to evaluate any criteria at the time of the current evaluation (for example, the evaluator does not know the answer because the technical specification is not yet ready), the criteria should be marked with "NA";
- The result gives a numerical value of integrated technology sustainability index (IASAM index) consistent with IASAM assessment framework. The integrated technology sustainability index evaluates the conformity with IASAM framework criteria. It is calculated as the sum of all values from the questionnaire and divided by maximum possible value of questions answered. This result is combined with UTAUT questionnaire results. UTAUT is aimed at potential users and gives information about technology acceptance:

$$IASAM_{index} = \frac{\sum_{j=1}^{38} A_j + \sum_{i=1}^{49} B_i}{(N - C) * 7} \quad (1)$$

, where A – UTAUT survey response values; B – IASAM survey response values; N – total number of questions; C – number of questions marked with "N/A".
The final result is then interpreted according to IASAM methodology.

- Afterwards, the procedure calculates the consistency of the result. This value E is called IASAM credibility and it looks at the number of questions left without value (those marked with N/A) and decreases the „internal credibility" of the value obtained in the previous step. The more questions marked with N/A, the less consistent is the result. This does not mean that the technology sustainability index is lower. The E is calculated as $E = C / N$.

Thus the measurement gives two results – the sustainability index and the credibility for the calculated index. Besides it is worth mentioning, that model allows making evaluation multiple times over period of time, gathering these results and comparing the evolution of the technology from IASAM perspective.

3.2. IASAM amendments - the need for a second version

Initially UTAUT model was used to evaluate user acceptance. The UTAUT combines other models and includes four key determinants for acceptance analysis: performance expectancy, effort expectancy, social influence, facilitating conditions; and four moderators: gender, age, experience, voluntariness of use[2]. The UTAUT survey is carried out separately and the results are used in two ways. First, separate analysis of UTAUT survey results gives

comprehensive understanding of potential user acceptance. And second, the integration of certain answers into IASAM results adds the acceptance perspective to the model.

The use of UTAUT involved potential user survey and that was the greatest difficulty connected with the IASAM evaluation. IASAM is planned to be a model that is applicable at any stage of technology development and potential user surveys might be very challenging for example:

- During early stages of technology development where no prototype is available;
- In cases were potential users are hard to reach, they are geographically widespread, distant from technology developers, etc.;
- In situations when there is no time for organizing a survey.

Therefore it was decided to change the methodology for user acceptance evaluation and to replace UTAUT and potential user survey with another approach. After a thought-out research it is concluded that the user acceptance evaluation can be expanded based on diffusion of innovations by Rogers[9]. The next section describes the foundation for this alteration.

4. Theory of diffusion of innovations

Research on diffusion is an interdisciplinary field and actually there is a vast and highly fragmented literature on diffusion of innovations. It is possible to identify different approaches to diffusion of innovations, each focusing on specific aspects of diffusion through different perspectives. The main contributions come from economics, marketing, sociology and anthropology[10].

One of leading theories regarding the questions introduced in this research is theory on diffusion of innovations by Rogers[9]. It is a remarkable research that has continued to evolve and influence many of the following research projects. Many of the models that attempt to explain the factors affecting whether an innovation will be shared and adopted by other individuals and organisations have been based on Rogers' diffusion of innovation theory[11]. It examines innovations from many perspectives. The extensive research includes innovation-development process, innovation-decision process, attributes of innovations and their rate of adoption, different adopter categories, as well as topics on leadership and change agents and innovation in organizations.

Rogers defines innovation as an idea, practice, or object that is perceived as new by an individual or other unit of adoption.[9] It should be noted here that Rogers often uses terms innovation and technology as synonyms. A technology, according to him, is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome.

The innovation-decision process, according to Rogers, is the process through which an individual (or other decision making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to decision to adopt or reject, to implementation of the idea, and to confirmation of this decision.[9]

Besides other important issues, Rogers speaks about attributes of innovations that take part in the innovation adoption process. He outlines that diffusion researchers in the past tended to regard all innovations as equivalent units from the viewpoint of study and analysis. This is an oversimplification, and a dangerous one. That all innovations are not equivalent units is evidenced by the fact that some new products fail and others succeed.[9]

The five attributes of innovations are:

- Relative advantage – the innovation is technically superior (in terms of cost, functionality, "image", etc.) than the technology it supersedes;

- Compatibility – the innovation is compatible with existing values, skills, and work practices of potential adopters;
- Complexity – the innovation is relatively difficult to understand and use;
- Trialability – the innovation can be experimented with on a trial basis without undue effort and expense; it can be implemented incrementally and still provide a net positive benefit;
- Observability – the results and benefits of the innovation`s use can be easily observed and communicated to others. [9]

This set of innovation attributes can be considered as the main contribution of Theory if Innovation Diffusion to our study.

5. The use of theory of diffusion for assessing technology acceptance

Practically, the part of IASAM where UTAUT criteria were used has been replaced in IASAM2 by these five attributes of innovations. But they had to be measured without involving the potential user survey. Therefore these criteria are aimed for self-assessment (see Table 1).

Table 1. Criteria for technology adoption evaluation

	Criteria	Criteria description
Relative advantage	Economic profitability	Economic profitability is an advantage of using this technology
	Low initial cost	Low initial cost is an advantage of using this technology
	Decrease in discomfort	Decrease in some kind of discomfort is an advantage of using this technology
	Social prestige	Use of this technology advances the social prestige of the user
	Savings of time/effort	Saving of time and/or effort is an advantage of using this technology
	Immediacy of the reward	The benefits of using technology are immediate a and that is an advantage of using this technology
Compatibility	Social/cultural values and beliefs	The use of technology is positioned as compatible with social/cultural values and beliefs
	Previously introduced ideas	The use of technology is positioned as compatible with previously introduced ideas
	With client needs	The use of technology is positioned as compatible with client needs
Complexity	Complexity of technology	The technology is positioned and should be perceived by potential users as easy
Trialability	Trial availability	There are mechanisms (free downloads, trial versions, prototypes), that enable the users to easily try the technology
Observability	Observability of technology	The results and benefits of technology is easily visible by potential users.

The same approach for evaluation is used here. The statement provided for each criterion (description) is evaluated in 7 point Likert scale. If it is not possible to evaluate any criteria at the time of the current evaluation the criteria should be marked with “N/A”.

Of course these amendments impact also other methodological issues:

- Changes the formula of IASAM2 calculation (see Table 2) are the following:

$$IASAM\,2_{index} = \frac{\sum_{n=1}^{12} F_n + \sum_{i=1}^{49} B_i}{(N-C)*7} \quad (2)$$

, where F – additional IASAM2 survey response values; B – initial IASAM survey response values, N – total number of questions; C – number of questions marked with "N/A".

- Additional validation is needed to validate these five criteria and the whole model together.
- Revision of result interpretation tables is needed to adjust them to the changes.

5.1. Comparison of IASAM and IASAM2

The substantial difference between IASAM and IASAM2 concerns the acceptance evaluation and corresponding activities. An overview of the basic differences can be seen in Table 2.

Table 2. IASAM and IASAM2 differences.

	IASAM	IASAM2
Acceptance evaluation	Potential user survey based on UTAUT methodology (38 questions)	Five criteria (12 additional questions) based on attributes of innovations according to Innovation Diffusion theory
Sustainability evaluation	49 questions	49 questions
Data gathering methods	Self-assessment questionnaire + potential user survey	Self-assessment questionnaire
Data processing and analysis	2 phases – UTAUT survey analysis and then conjoint IASAM analysis	Integrated IASAM2 analysis
Result interpretation	UTAUT results are presented separately and within IASAM	IASAM2 results are presented in an integrated way

The newest IASAM2 version has several significant benefits:

- The assessment can be carried out by the interested party oneself;
- There is no need for time and resources-consuming potential user survey;
- The model itself becomes more comprehensible, as the calculus, analysis and reporting can be done within one methodological framework;
- IASAM2 meets the initial goals of this tool – to be easy to use and universal in its applications.

Thus the final IASAM2 approach can be viewed as the following sequence of processes that may be repeated over time according to the needs of evaluator (see Fig. 2).

5.2. IASAM2 validation

As already mentioned, the initial IASAM version was validated against Skype and then used for socio-technical evaluation of actual products within FP7-ICT-2009-5 CHOReOS project No. 257178 (2010-2013) *"Large Scale Choreographies for the Future Internet (IP)"*[8]. Within this project eight products were evaluated. For the purposes of validation, the same evaluations should be carried out. Evaluation of Skype and the same CHOReOS products with IASAM2 and comparison of the results would help to understand whether the updated version is usable and the results satisfy the needs. The Table 3 shows the values of evaluations done with IASAM and IASAM2.

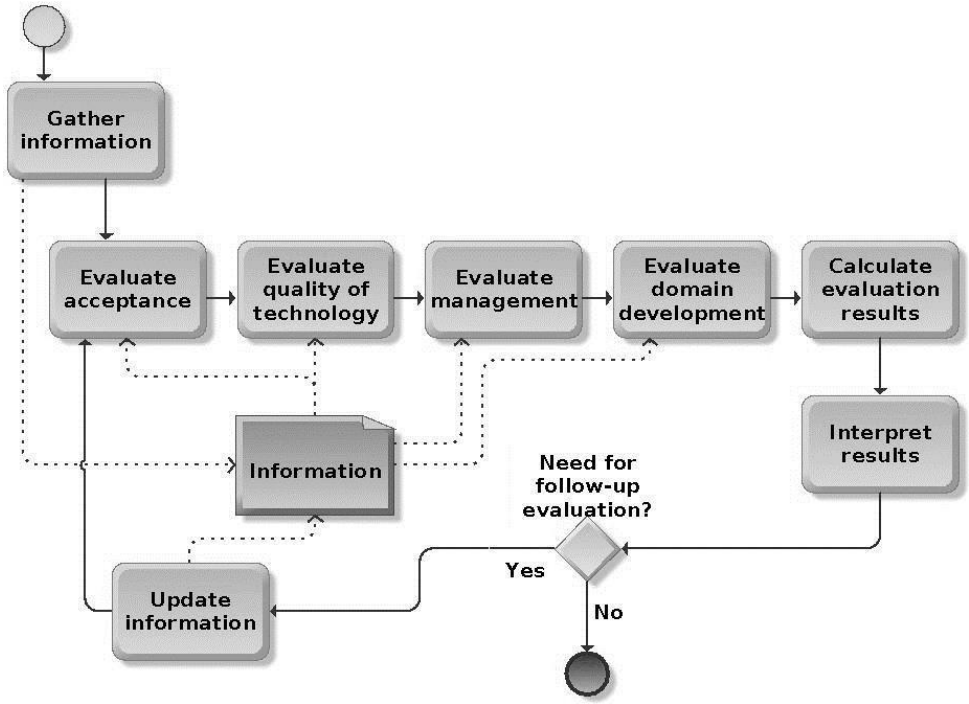

Fig. 2. Assessment in conformity with IASAM2 rules.

Table 3. Overview of IASAM and IASAM2 generated evaluations - IASAM index values.

	IASAM	IASAM2
Skype	0.91	0.86
ACRB	0.83	0.79
Passenger Friendly Airport	0.69	0.70
Middleware	0.80	0.84
DynaRoute	0.78	0.76
V&V tools	0.64	0.62
Service Bus	0.73	0.75
IDRE	0.69	0.69
Cloud and grid	0.74	0.76

The differences are no more than 0.05 and it can be concluded that the replacement of potential user survey based on UTAUT with self-evaluation questions based on Theory of Diffusion of Innovations, does not violate the internal integrity of IASAM model and generates accurate and usable evaluations as well. It meets the aims of the model and can be used for sociotechnical evaluation of ICTs.

Provided approach allows using Skype as IASAM index unit of measurement. For example, evaluation of Passenger Friendly Airport in conformity with IASAM2 is 0.70 units or 0.81 skypes.

6. Conclusion

IASAM serves as a self-assessment (but not limited only to the developer) tool for developing technologies or innovations and provides easy to use methodology to carry out assessments at any point of technology development. IASAM consists of four groups of factors that have an impact on integrated technology acceptance and sustainability – Management, Quality of technology, Acceptance and Domain development. By using system dynamics simulation the model allows its users to monitor the variation of the IASAM index over time.

After changing acceptance evaluation criteria from UTAUT to innovation of diffusion approach, the model has become even more comprehensive. Validation process ensures that IASAM2 model provides accurate evaluation. This kind of evaluation tool can be useful to idea owners, technology developers, investors, government officials and researchers for estimating the prospects of a new technology.

Nevertheless research could be extended to define whether this methodology can be adjusted to technologies in a broader sense, not only ICTs.

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